Optical Radiation Measurement Club

Meeting

The Artificial Optical Radiation Directive -
Regulation, Standards, Measurement and Implications for UK Employers

National Physical Laboratory
23rd May 2007
Welcome

It is a great pleasure for the Optical Radiation Measurement (ORM) Club to welcome you to the National Physical Laboratory (NPL). The ORM Club was formed in 1998 to act as a forum for discussion for all those with an interest in optical radiation measurements, whether this relates to the properties of sources, detectors, or materials. Over the years the Club has organised more than 30 workshops or seminars, which have been highly successful in bringing together researchers from industry, academia and metrology, and we are delighted that you are able to join us for this latest event in the Club calendar. If you would like to find out more about the NPL ORM Club, please contact Fiona Jones (fiona.jones@npl.co.uk) or visit the Club website at http://www.npl.co.uk/optical_radiation/ormclub/.

Thank you for your participation at this meeting, and we hope that you enjoy your time at NPL.

Simon Hall – Technical Chair
Jessica Cheung - ORM Club Secretary

Bushy House

Bushy House is a historic royal residence and the birthplace of the National Physical Laboratory. If you are interested, information about the history of Bushy House can be found at the reception desk.

Refreshments

During breaks, lunch and drinks will be served in the Entrance Hall. You are welcome to take your lunch outside into the gardens of Bushy House. There are tables and chairs set up both inside and in front of the Orangery.

Other information

If you leave the site at all please remember to carry your NPL visitor’s badge. You will not be allowed on site without it. With your badge you will be able to use the Queens Road entrance to NPL. We would appreciate it if you would also return your badges at the end of the meeting.

We would also appreciate it if you could fill in the questionnaire before you leave – this information is of great value to us and will help us improve our meetings.
Future meetings

ORM Club Annual Meeting: 27\textsuperscript{th}-28\textsuperscript{th} June, Bushy House, NPL, Teddington

This is an exciting year for the Club. NPL’s Optical Radiation Measurement Team has recently been re-structured, and has now joined forces with the Photonics Team. Together we have formulated our next programme of government-funded work, covering new and challenging themes while continuing to maintain and improve our core metrology work in providing standards for the UK community. The ORM Club Steering Committee met earlier this year to discuss the opportunities that this re-structuring offers for the Club and this will be reported at the meeting. As this is your Club we strongly encourage you to bring along ideas for themes that you feel we should cover – discussion time has been made available at the end of the first session. We will also present some new web features to enhance the networking opportunities that the Club provides.

In addition to launching the new Club structure, we will have a programme of talks on the topics of optical radiation field measurements and imaging and translucency, together with sessions to provide feedback on international standardisation committees and organisations, progress within the Club FIGs, and other recent developments in optical radiation measurements and technologies. More details will be available on the website when the programme is confirmed.

OFMC: 15th - 17th October 2007, Teddington, UK

OFMC is Europe’s leading conference on measurements of optical fibres and optoelectronics. OFMC brings together scientists, technologists, metrologists and industry specialists to discuss issues and developments in measurements for applied optical technologies. Optical technology is being applied across a wide range of industries from automotive engineering to medicine and biology. The increasing role of fibre optics and optoelectronics presents not only opportunities, but also measurement problems, which need to be solved.

The meeting will consist of invited and contributed papers. Contributions are sought on all experimental and theoretical aspects of measurements in guided light technology.

For more information visit the website below.
http://www.ofmc2007.npl.co.uk/
Meeting Abstract

The Optical Radiation Measurement Club at the National Physical Laboratory is holding a one-day meeting on the regulation, standards and measurement of artificial optical radiation in the workplace and implications of the EU Physical Agents (Artificial Optical Radiation) Directive for UK employers and employees. This is intended to capture and refine the views of UK users and manufacturers by group discussion to inform the regulatory process and ensure new regulation does not conflict with the interests of the UK economy.

The Artificial Optical Radiation Directive (AORD) was published in the Official Journal of the European Communities on 27 April 2006 (Ref: L114, pp 38-59) under the title of “Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation)” It no longer contains the reference to the sun as a hazard, as initially reported in the media.

EU Member States have until 27 April 2010 to produce national legislation to implement the AORD; in the UK, this task resides with the Health and Safety Executive. Employers will need sufficient information from equipment suppliers to allow them to do the required assessments. It may be that the Directive will encompass exposure of the public depending upon the implementation of the Directive into UK regulation. Hospital staff will definitely be included. One of the problems employers will face is the combination of effects of different optical sources within the workplace.

For more information on the meeting please see:
<http://www.npl.co.uk/optical_radiation/ormclub/meetings/otm_may2007/index.html>

References:
A link to the text of the directive can be found at
http://www.hse.gov.uk/radiation/nonionising/optical.htm or directly at

A review of the text is recommended before attending the meeting.
Programme

09:30 Registration and coffee

Chair: Simon Hall and Neil Haigh

10:00 Welcome
Simon Hall, NPL

10:05 Regulation required by the Artificial Optical Radiation Directive
Steve Walker, Heath and Safety Executive

10:35 Artificial Optical Radiation Directive - Exposure limits and discussion of supporting standards framework
John O’Hagan, Health Protection Agency

11:05 Coffee break

11:20 Measurement overview
Simon Hall, NPL

11:40 Panel discussion
Steve Walker, John O’Hagan, Simon Hall, Neil Haigh (Chair)

12:20 Lunch and Exhibition

13:30 Further comment on panel discussion

Chair: Andrew Coleman

13:45 Medical implications of the Artificial Optical Radiation Directive
Harry Moseley, Ninewells Hospital, Dundee

14:00 Solid state lighting: activity and growth
Geoff Archenhold, Photonics Cluster UK

14:15 Environmental Risk Analysis of Ultraviolet Phototherapy Centres in Ireland
Neil O’Hare, St James's Hospital, Dublin,

14:30 Tea break

15:00 The effects of the Artificial Optical Radiation Directive on millimetre to THz optical radiation: security, pharmaceuticals, research environment
Richard Dudley, NPL

15:15 High power light sources used in medicine
Stephen Bown, Royal Free and University College Medical School, London

15:30 Intense medical light sources: standards development in IEC 60601 and IEC 60825-16
Bill Davies, Swansea NHS Trust

15:45 Intense pulsed light (IPL) source measurement at NPL
    Paul Miller, NPL

16:00 Open Discussion (chair: Simon Hall)
    Delegates and Speakers

16:30 Close
Abstracts

Regulation Required by the Artificial Optical Radiation Directive

Steve Walker
Health and Safety Executive
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This talk will discuss the content and UK implementation plan for the Physical Agents (Artificial Optical Radiation) Directive (2006/25/EC).

Artificial Optical Radiation Directive - Exposure Limits and Discussion of Supporting Standards Framework

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The Artificial Optical Radiation Directive includes Exposure Limit Values (ELVs) derived from guidance published by the International Commission on Non-Ionizing Radiation Protection. These ELVs will be outlined for laser and non-laser exposure situations. Some of the issues arising from the continuing development of exposure guidelines will be described.

The Directive is not specific on how exposure assessments should be carried out but makes reference to standards of the International Electrotechnical Commission for lasers, and recommendations of the International Commission on Illumination and the European Committee for Standardisation for non-coherent radiation. The challenges presented by this will be described, along with an outline of some of the standards that are available to assist employers.

Where standards do not currently exist to assist employers it is important that guidance is produced in a reasonable timescale and preferably before the UK has to implement its own legislation, i.e. by April 2010. Perhaps the main objective should be to indicate to employers where the risk of exceeding the ELVs is so low that an assessment is not necessary.

Measurement Overview

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The Artificial Optical Radiation Directive (AORD) was published in the Official Journal of the European Communities on 27 April 2006 under the title of “Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation)”.

The Directive refers to the International Commission on Non-Ionising Radiation Protection (ICNIRP) exposure limit values for laser and non-coherent radiation. Non-coherent radiation is defined, for the Directive, as optical radiation other than laser radiation. The exposure limits are included as two annexes to the Directive.

It is not expected that workplace measurement will be the norm, but situations with multiple optical sources which approach the exposure limits incorporated in the directive may require measurement as a simpler alternative to complex calculation of the possible interactions of the installed sources with each other and the physical structure of the workplace.

The rapidly evolving availability and subsequent use of intense light sources in industrial, domestic medical and research environments will require increasing measurement rigour by manufacturers and integrators to ensure that these products will not generate problems for UK employers wishing to use their products. Methodologies for measurement of these novel sources and a robust traceability route will be required for situations where questions may arise over the potential hazard of optical sources.

From the directive:
“In carrying out the obligations laid down in Articles 6(3) and 9(1) of Directive 89/391/EEC, the employer, in the case of workers exposed to artificial sources of optical radiation, shall assess and, if necessary, measure and/or calculate the levels of exposure to optical radiation to which workers are likely to be exposed so that the measures needed to restrict exposure to the applicable limits can be identified and put into effect. The methodology applied in assessment, measurement and/or calculations shall follow the standards of the International Electrotechnical Commission (IEC) in respect of laser radiation and the recommendations of the International Commission on Illumination (CIE) and the European Committee for Standardisation (CEN) in respect of non-coherent radiation.”

“In exposure situations which are not covered by these standards and recommendations, and until appropriate EU standards or recommendations become available, assessment, measurement and/or calculations shall be carried out using available national or international science-based guidelines.”

Medical Implications of the Artificial Optical Radiation Directive
Prof. Harry Moseley
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Areas in which the Directive will apply
Optical radiation is widely used in the healthcare sector for a broad range of diverse procedures. These include:
• Laser and intense light treatment
• UV phototherapy
• Neonatal phototherapy
• Photodynamic therapy
• Optical radiation diagnostics
- Endoscopy
- UV sterilisation
- Bio-stimulation

Other cosmetic applications are also included, such as:
- UV tanning
- Photorejuvenation

**Persons affected by the new Directive**

The Directive applies only to workers, and so patients are excluded (as are other members of the public). Implementation of the Directive requires a risk assessment to be carried out and steps taken to ensure that workers are not exposed above the exposure limit values. The limit values are based on the IEC laser standard, and the CIE and CEN broad-band standard. These are the standards that are currently employed and so the Directive should not have a significant impact on centres that are meeting these standards already. However, whereas previously occupational exposure levels were used as guidance these limits are now mandatory.

Special attention should be given to the health of workers belonging to particularly sensitive risk groups. These are not defined in the Directive and so clarification will be required in notes of guidance. It may refer to individuals who suffer from photodermatosis, which is a group of diseases that cause light-activated skin reactions. The exposure limit values do not apply to such individuals, who will need to be carefully assessed.

The effects on workers’ health from workplace interactions between optical radiation and photosensitising chemicals will also need to be assessed. This should be in place at present because many substances, such as certain antibiotics, fragrances and sunscreen ingredients, are known to interact with light to cause phototoxicity and photoallergy.

**Examples of the application to particular areas**

1. **Laser treatment**

   In the case of laser therapy, staff are regularly working in Controlled Areas where emission levels exceed exposure limits. There is a hierarchy of protection which will still be preserved: 1. engineering controls; 2. administrative controls; 3. personal protection. This should not change with the introduction of the Directive. It will remain true that reliance on the use of personal protective equipment will be the strategy of last resort. As noted above, safety of the patient is not a consideration under the new Directive. Likewise members of the public, for example patients in the waiting room or relatives accompanying a patient, are not included. The Guidance on Safe Use of Lasers issued by Medical Devices Agency is generally used within the healthcare sector and this refers to the IEC laser standard, as in the Directive.

2. **UV Phototherapy**

   UV Phototherapy is usually administered as an outpatient service in dermatology. UV levels within the treatment cabin exceed the exposure limits and so steps must be taken to ensure that staff working in these units are not exposed to levels that exceed the exposure limit, which is cumulative over an 8-hour day. This will apply to nursing staff who administer the treatment and physics staff who perform the dosimetry. Also, it should be noted that photodermatosis is generally provoked by exposure to UV radiation in sensitive individuals.

3. **Neonatal Phototherapy**

   Neonatal phototherapy involves the exposure of new-born babies to light (usually blue light) to
break down bilirubin in the treatment of neonatal jaundice. As before, the focus of the Directive is not on the exposure of the baby or the relatives visiting the baby but to the staff working in the unit. Most neonatal baby care centres have several special purpose incubators equipped with blue lights and these are more or less in continuous use. It will be a requirement under the Directive to show that staff are not exposed to levels that exceed the exposure limit. In this case, the so-called blue light region is likely to be the most restrictive.

Discussion

In terms of optical radiation safety, the year 2007 is to be noted as the year when the International Electrotechnical Commission (IEC) committee on laser safety committee took the decision to remove light emitting diodes (LEDs) from the scope of the main international standard on laser safety (IEC 60825-1), transferring their responsibility in terms of optical radiation hazard assessment to the corresponding lamp safety standard IEC (62471).

History will also show however that 2007 was the year when the performance metrics for High Brightness LED (HB LED) sources broke through significant barriers for properties such as efficiency, and efficacy, and, importantly from within the context of eye safety, the radiant intensity (which is defined as the radiant power emitted into the solid cone of the beam divergence). The relatively high radiant outputs of the latest generation of HB LEDs which is of the order of 100s of mWs (compared hitherto to 10s of mWs) allows these sources to be used in all kinds of general illumination applications and products, however it is now essential that any corresponding eye hazard must also be addressed, with some degree of urgency.

Other aspects of HB LED technology which are developing in pace with the increasing HB LED radiant intensity values are:

a) the reduction in the size of the LED emitter

b) the use exotic secondary optics for beam control purposes.

c) Development of bright blue LEDs

The sizes of the light emitting diode (i.e. the physical size of the light emitting 'chip') are being reduced from a dimension that was initially of the order of 5 mm in diameter, down through 1 mm diameter, to a dimension perhaps as small as 500 microns. From the optical radiation hazard perspective, the reducing size of the emitter has an interesting implication for the corresponding size of light spot delivered to the retina at the back of the eye. All things being equal, the smaller the source of light emission, then the smaller the retinal spot when the source is viewed by eye, and for a given radiant power output from the LED, the smaller the retinal spot size, the higher the likelihood of a retinal injury occurring.

The various optical radiation standards define a minimum possible retinal spot size via the concept of the source subtense angle parameter (α); this parameter can be defined for a ‘bare’ LED chip emitter as follows:
For example an LED chip which is 1 mm in diameter will, when viewed from a distance of 200 mm, have a corresponding source subtense angle of 5 mrad. The laser safety standard defines a minimum value for the source subtense angle of 1.5 mrad ($\alpha_{\text{min}}$) below which the source is defined as being ‘small’ such that it is perceived by the eye as a small ‘pinprick’ of light in the field of view (provided of course that the LED emission is visible); the distance at which the LED is perceived to be ‘small’ is referred to as the Small Source Viewing Distance, and for a 1 mm LED, the Small Source Viewing Distance can be determined to be of the order of 660 mm: beyond this distance the LED is effectively a ‘small’ source of light similar in output when viewed, as a laser.

It follows that an LED whose diameter is 500 microns will have a corresponding Small Source Viewing distance of 330 mm. Incidentally at the recommended measurement distance of 200 mm that is to be used for a ‘lamp’ hazard assessment according to IEC 62471 the LED source subtense angle is 2.5 mrad which is close to the minimum achievable value defined by $\alpha_{\text{min}}$. The specific value of the subtense angle is very important for the hazard assessment because for the case where the subtense angle $\alpha > \alpha_{\text{min}}$, the corresponding maximum permissible exposure to the beam can be raised somewhat above the worst case scenario that is to be applied for a ‘small’ (i.e. point like) source. Thus for the case of a 500 micron diameter visible LED, the retinal photothermal hazard exposure limit is raised by a factor of around 1.6x the corresponding limit for the equivalent laser.

At viewing distances where the LED subtense is only of the order of several mrad s the LED source is very much akin to a divergent laser in that it will deliver a physical small spot to the back of the eye. Thus in terms of today’s high brightness LED sources, it raises the question as to whether there is in fact any merit at all in having two slightly differing optical radiation safety standards when the only concern that really matters is of course whether an eye injury is likely to occur. And this concern exists regardless of whether source of potentially hazardous optical radiation is a laser, LED or indeed a very intense lamp. In the case of a 500 um HB LED, the radiant power and beam divergence will very likely be the two key properties of the source that determine the whether the corresponding the retinal spot is hazardous.

In terms of secondary optics, all manner of lenses, mirrors, and total internally reflecting facets are being used with today’s high brightness LEDs in applications where there is for example a need to reduce the beam divergence, or deliver a specific amount of light-on-task. The use of secondary optics creates problems from the optical radiation safety point of view in that it is no longer a straightforward matter to determine the source subtense angle, as both the (apparent) source size and (apparent) source location must be determined for use in its calculation. Note that in equation (1) above it is not necessarily correct to simply use the LED chip size and physical distance from the observer to determine the subtense angle: the ‘apparent’ values must be used instead. Unfortunately, IEC 62471 does not address the determination of the subtense angle ($\alpha$) (and/or the related ‘apparent’ dimensional values for a LED featuring a secondary optic), and this must be a major concern for the adoption of this standard by the LED community.

Finally, recent years have seen a proliferation of bright blue LEDs whose centre wavelength is close to or indeed centred on the peak of the blue light photochemical hazard region of the spectrum around 440 nm, the implication here is that long term eye exposure to these sources could be harmful, akin to a background UV type of exposure albeit it to the retina, and for which there is now a need to review urgently whether there is genuine to adopt precautions in the use of
such LEDs, especially in the research and development phase where workers in the field are likely to be exposed to the source output for considerable periods of time during the working day. This area of concern is referred to as the ‘blue light hazard’ (BLH) and must be addressed for the current and next generation of high brightness LEDs whose output is dominant in this region of the spectrum. The following figure shows the output of a typically white light HB LED overlaid against the blue light hazard function – it can be seen that in the blue end of the spectrum, the peak spectral output coincides with the peak of the BLH; such LEDs usually appear to the eye to have a slight tinge of blue in their otherwise white output.

**Figure 1: CIE Blue Light Hazard Function and White LED Output**

**Generic EU OARD Standard Proposal**

The EU Artificial Optical Radiation Directive (AORD) presents a useful opportunity for the European Community to address the deficiencies within and confusion caused by the *de facto* establishment of two separate international standards on LED (i.e. ‘lamp’) and laser safety. Furthermore, these standards cannot be considered harmonized (as is stated) in that they have different product (safety) labeling requirements and differing measuring conditions.

It is proposed therefore in this discussion document that the AORD be used to create a single set of harmonized optical radiation standards that do not need to be specific to the nature of the source of light i.e. whether or not it is a laser, LED or a lamp; this is actually moot from the perspective of a potential eye injury. It can be found via an assessment of the various standard documents that there are only two key features of a light source that determine how its hazard should be assessed:

- Whether the source is ‘small’ or ‘extended’ (as defined by the subtense angle)
- Whether the source is narrowband or broadband (as defined by the source linewidth)

Given these two properties it follows that any source of optical radiation can be categorized as
being of one of four generic types:

i  Narrowband and small source (e.g. a laser pointer)
ii  Narrowband and extended source (e.g. large single colour LED, diffuse spot of laser light)
iii  Broadband and small source (e.g. 250 um white HB LED, white LED launched into an optical fibre)
iv  Broadband and extended source (e.g. white light LED, UV lamp)

The examples listed above are for illustration only, because the generic approach requires only that the apparent source size and spectral linewidth be determined, rather than a decision made as to whether the source is to be treated as laser or as a LED (as is required at present within the context of the IEC safety approach.) Even so, for either IEC standard, the apparent source size must be determined in any case.

The categorization of a light source into 1 of 4 types implies that only four generic safety standard documents be written, the technical content of which exists already and which can be readily assimilated from the existing ‘body of knowledge’ of optical radiation safety.

It follows from this proposed generic approach to optical radiation safety, that relatively brief product specific safety standard documents could be developed as needed for new products, but which themselves do not need to repeat the entire ‘body of knowledge’ of optical radiation safety which occurs at present. Instead, the product safety document can concentrate on the pertinent safety issues from the ‘user’ perspective; separate EU product safety standards could be written as needed for items such as laser pointers, LED torches and Intense Pulsed Lamps, and these would be relatively straightforward documents to read, without needing to follow the complex details of optical radiation safety which is best documented elsewhere within the above 4 generic safety standards.

**Measurements for Optical Radiation Safety**

Regardless as to which approach is taken towards addressing the EU Directive on optical radiation from the perspective of lasers and high brightness LEDs, critical concerns still remain from the measurement point of view:

- How to measure the apparent source size
- How to calibrate broadband optical radiation safety measurement equipment (e.g. for measurement of LED power spectral density in watts per nm.)
- What is the most appropriate position (distance) at which to measure the hazard posed by the source
- Whether or not optically aided viewing is to be included in the assessment
- The measurement and hazard assessment of LED arrays

All of the above require further study and apply regardless of whether an LED is to be treated as a ‘laser’ or a ‘lamp’.
Environmental Risk Analysis of Ultraviolet Phototherapy Centres in Ireland

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Ultraviolet Radiation (UVR) is widely used in the treatment of dermatological conditions such as psoriasis and eczema. It is known that high levels of exposure to UVR will increase the risk of biological effects such as skin cancer and cataracts. UV Phototherapy centres are typically located in adapted general purpose treatment rooms and clinics, and can take place for an 8-hour day, up to five days a week. This could involve a significant level of occupational exposure for clinic staff. Exposure limit values for UVR have been developed by the International Commission for Non-Ionising Radiation Protection (ICNIRP). Recently the Physical Agents Directive (Artificial Optical Radiation) was issued by the European Commission for transposition into law in each of the member states by 2010. Occupational exposure to Phototherapy staff should be kept within these limits. The use of environmental controls such as warning signs, good ventilation and UV-opaque curtains will significantly reduce the risks to staff, patients and members of the public. An environmental risk assessment has been carried out at 11 of the 20 Phototherapy centres in the Republic of Ireland. The study assessed a number of areas such as: patient safety, staff safety, room design and UV leakage measurements. The aim of the study is to identify hazards in Phototherapy centres and present recommendations for reducing risks. The results show that on the whole there is a good level of risk management in Phototherapy Centres, although there are still a number of hazardous issues that need to be addressed.

The effects of the Artificial Optical Radiation Directive on millimetre to THz Optical Radiation: Security, Pharmaceuticals, Research Environment

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Sources of coherent Terahertz radiation have only recently emerged and as a consequence safety requirements have been loosely defined from high-microwave and far-optical band definitions. With increasing Terahertz power levels and more commercial products becoming available for medical and security scanning, the definition of safe levels may be inadequate. This talk will present the current and future range of THz sources as a discussion point to enable future definitions of safety and exposure levels.
This presentation reviews the use of high power sources of non-ionising optical radiation in clinical practice. By far the most important group is lasers. The nature of the interaction of laser light with living tissue depends on the wavelength, beam characteristics (CW or pulsed and if pulsed, the pulse duration, repetition rate etc), spot size, power and total energy delivered.

The tissue interactions can be divided into 3 main groups:

- Photoacoustic
- Thermal
- Photochemical

**Photoacoustic**

The best established application is the use of a pulsed excimer laser to reshape the front of the eye to correct refractive errors and reduce the need for glasses, especially in young people. Less widely used, a highly focused pulsed NdYAG beam can clear opaque membranes in the front of the eye after cataract surgery. Pulsed dye lasers can crack kidney stones.

**Thermal effects**

These are the most widely used. The CW carbon dioxide laser (up to 30 W) is effective for ablating many small skin lesions and as a non-contact knife, although tissue penetration is so superficial (<0.1 mm) that it can stop no more than minimal oozing. It is difficult to use internally as no convenient fibre systems are available, but experimentally 800 W CO₂ lasers have been used for punching holes in the myocardium to revascularise diseased hearts.

The best tissue penetration (which optimises control of bleeding) is achieved with near IR lasers (800-1300 nm) and these beams can be transmitted easily via flexible fibres (0.3 mm diameter). They can be used in conjunction with flexible endoscopes in organs like the oesophagus and major airways, to core out obstructing cancers with minimal blood loss (eg NdYAG laser at 1064 nm, power up to 70 W). At much lower power (up to 5 W), fibres from these lasers can be inserted through needles to ablate (“gently cook”) lesions in solid tissue like breast, liver and bone. The Holmium YAG (2.1 µm) is used to treat enlarged prostates.

**Photochemical effects**

The fastest growing new application of lasers in medicine is in Photodynamic Therapy (PDT), particularly for treating a range of tumours. This is when low power, red laser light (630-760 nm, typically up to 200 mW/cm² externally or 250 mW/cm if used with diffuser fibres interstitially) is used to activate previously administered photosensitising drugs. No heat is involved, so the effect is gentler on tissue and healing is better than after most other forms of local treatment, especially in cosmetically and functionally important areas like the skin and mouth.

The high power thermal lasers are potentially the most hazardous, both because of the high power levels used and because the main beam is in the IR spectral range and so invisible. For these instruments, it is obligatory to have a visible aiming beam delivered through the same system and
an audible warning when the laser is firing. The near IR lasers are almost always used through fibres, which emit a divergent beam, so reducing the hazard as the distance from the source is increased, but strict safety precautions are essential. Lasers used for PDT have a visible main beam and much lower power, but this is still in the hazardous range, so again precautions are required for protection of all individuals who could be exposed to the beam.

Some non-laser light sources are used. In the visible range, arrays of LEDs are increasingly used, designed to illuminate surface areas and for some internal organs. For external use, filtered xenon lamps have been used for PDT, although it is difficult to filter these to exclude the infrared light.

Examples of each type of application will be shown, for discussion in the context of the European Optical Radiation Directive.

**Intense Medical Light Sources: Standards Development in IEC 60601 and IEC 60825-16**

Bill Davies
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In order to address operational and safety issues from intense light sources used in Medical and Cosmetic applications two IEC documents have been drafted and circulated to national committees.

The UK has the lead for the drafting of these documents and through this an opportunity to provide comment at an early stage.

The current position regarding the development and outstanding technical issues will be discussed in the light of the need to protect employees who may be exposed to this equipment.

**Intense Pulsed Light (IPL) Source Measurement at NPL**

Paul Miller¹, Ewan Eadie², Teresa Goodman¹, Harry Moseley²

¹ National Physical Laboratory, Teddington, UK
² University of Dundee, Photobiology Unit, Ninewells Hospital & Medical School

**Introduction:** More than 20,000 intense pulsed light (IPL) sources are already in use worldwide for applications such as hair removal and skin treatment. The optical radiation presents a hazard to the eye and skin, and incidents of damage are increasingly being reported. The European Physical Agents Directive on Artificial Optical Radiation requires that employers must be able to prove through their risk assessment that employees are not being exposed to levels of artificial optical radiation in excess of the Exposure Limit Values set by the Health Protection Agency and the International Commission on Non-Ionising Radiation Protection (ICNIRP). In many cases, this is likely to require complex calculations and/or measurements. In collaboration with the Photobiology Unit at Ninewells Hospital, the National Physical Laboratory identified the measurement of IPLs as a priority need of optical radiation dosimetry in healthcare. Measurement systems have been developed to capture spectral and temporal information of IPLs, traceable to national standards.

**Materials and Methods:** Time resolved spectral output of a commercially available IPL was
measured using an Andor spectrograph with fast kinetic CCD camera system. This system is able to capture spectral information in sub-millisecond periods of time. Longer capture times allow measurement of the entire pulse train and improve the signal to noise ratio. Using this system the changes in the spectrum that occur during a single pulse were recorded (Figure 1). Temporal measurements were made with a NPL calibrated silicon photodiode, connected to a fast amplifier and controlled by computer software.

**Results:** Spectral output was captured for four different treatment handpieces:

1. 585 nm Treatment Handpiece
2. 650 nm Treatment Handpiece
3. Acne Handpiece (Figure 1)
4. Selective Vascular Handpiece

Measurement was between 500 nm and 1000 nm with a spectral resolution of 0.66 nm. A 450 ms capture time was used in the measurement of pulses with duration between 1 ms and 7 ms. Time averaged spectral output can be calculated from the time resolved data (Figure 2).

Pulse shape, duration and delay were all measured with the photodiode system. The measurement of pulse duration (and delay) shows good agreement between the spectrograph and photodiode systems.

**Conclusions:** A detailed and accurate characterisation of the IPL system has been made between 500 nm and 1000 nm. The CCD array system provides good spectral resolution and is able to capture time resolved spectral information over very short durations. When considering such a system for measuring IPL sources the accuracy of results is dependant upon a number of factors, including: spectral response calibration, wavelength calibration, internal stray light, linearity and second order radiation.

![Figure 1](image_url): Time resolved spectral output of IPL Acne Handpiece, with OG515 filter showing the spectral variation within a single pulse. Capture time is 400 μs.
Figure 2: Time averaged spectral output of consecutive pulses of a pulse train from an IPL 585nm Treatment Handpiece. Capture time is 450 µs.